

**Paleomagnetic study and
dating of core SOH4**

Preliminary report
August 1993

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I - Sampling

The first sampling of this core for a paleomagnetic study has been made by Carlo LAJ (CFR, Gif-sur-Yvette) and Emilio HERRERO-BERVERA (SOEST, Honolulu) in March 1993. Three short plugs were taken close to each other at each level (about one set in each box). A total of 494 plugs were taken from 180 different levels (flows and very few intrusions). Each plug gave one specimen for the paleomagnetic analyses. The sampled length of the core is about 2010 feet down from the top of the core. Between 763 and 867 feet, only intrusions have been sampled. The tables in which the sampling is detailed are reported in Appendix 1.

Just above 1550 feet, a piece of core has been taken (about 7") for radiometric dating.

II - Paleomagnetic study

Only the flows and not the intrusions have been studied so far.

II-1. Study of the Natural Remanent Magnetization (NRM)

One specimen per flow was analysed systematically at room temperature. Four parameters were measured: the low-field susceptibility value, the declination and the inclination values. All the numerical tables are reported in Appendix 5.

a) The low field susceptibility values has been normalized by the mass of the samples so that the values are independant of the proportion of vesicules in the rock. This parameter is highly variable along the core (Figure 1A). It ranges from $4 \cdot 10^{-5}$ SI/g to almost $300 \cdot 10^{-5}$ SI/g. In order to have a better look of the majority of the data that range between 4 and $100 \cdot 10^{-5}$ SI/g, we have expanded this part of the diagram in Figure 1B. A value of $20 \cdot 10^{-5}$ SI/g can be considered as the mean value for the sampled length of the core.

b) The declination values have no meaning because the different segments are

Low-field susceptibility values
normalized by the mass

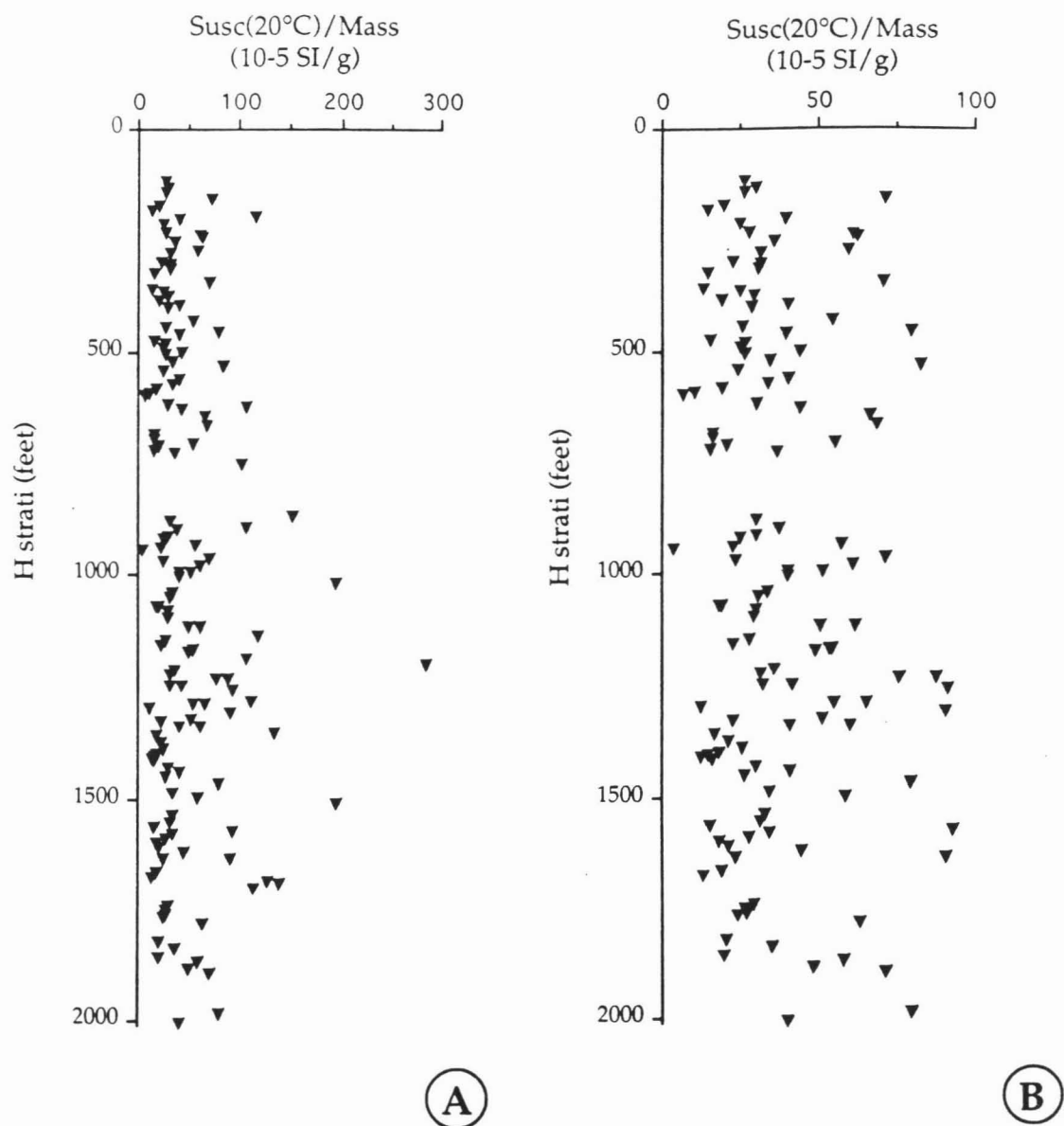


Figure 1

not oriented (Figure 2).

c) The inclination values are mainly positive (Figure 2). The top part of the core (down to about 900 feet) is consistent with the present day field inclination value in Hawaii (about 36°). Below, the values are shallower. There are some specific points that show negative values of the NRM inclination: specimens n°19, 142, 145, 232, 238 and 239, 330 and 331, 336, 354, 492 that correspond to flows n°7, 52, 54, 83, 85, 115, 117, 123, 176 respectively. These negative inclination values can be due to secondary overprint and they must be checked as all the other directions by stepwise demagnetization.

II - 2. Thermal demagnetization

As a first analysis, 33 samples were thermally demagnetized. We chose one specimen every 6 flows in order to get a first idea of the total sampled length of the core. Each specimen has been demagnetized using 12 steps between room temperature and 570°C . The steps are the following:

$20^\circ\text{C} - 120^\circ\text{C} - 180^\circ\text{C} - 240^\circ\text{C} - 300^\circ\text{C} - 350^\circ\text{C} - 400^\circ\text{C} - 450^\circ\text{C} - 500^\circ\text{C} - 530^\circ\text{C} - 550^\circ\text{C} - 570^\circ\text{C}$.

At each step the susceptibility value has been measured in order to monitor eventual changes in the magnetic mineralogy during heating. The results obtained from each specimens are illustrated by the diagrams given in Appendix 2:

- the orthogonal projections demagnetization diagrams (block dots: projection onto the horizontal plane; white dots: projection onto the vertical planes).
- the curve of decrease of the intensity during heating (J/J_0 ; black dots) with the evolution of the susceptibility value (X/X_0 white dots).
- the stereographic projection of the paleomagnetic directions during the demagnetization. The concentric circles indicate the direction at room temperature. The vectorial differences are also reported with their associated number. Below the stereographic projection, the numerical table is reported.

(Etape = step; Res = resultant intensity in A/m; Dec and Inc = declination and inclination values, DD and DI = declination and the inclination values of the vectorial differences; DRE% = percentage of intensity decrease with respect to the previous step.)

In the great majority of the cases, the direction of the magnetization does not change significantly from room temperature up to 570°C . The intensity decreases very little between 20°C and about 300°C and at 570°C , only about 1% of the initial intensity value is left. The direction of the Characteristic Remanent Magnetization

NRM declination and inclination values from flows of
core SOH4
(2.000 feet from the top of the core)

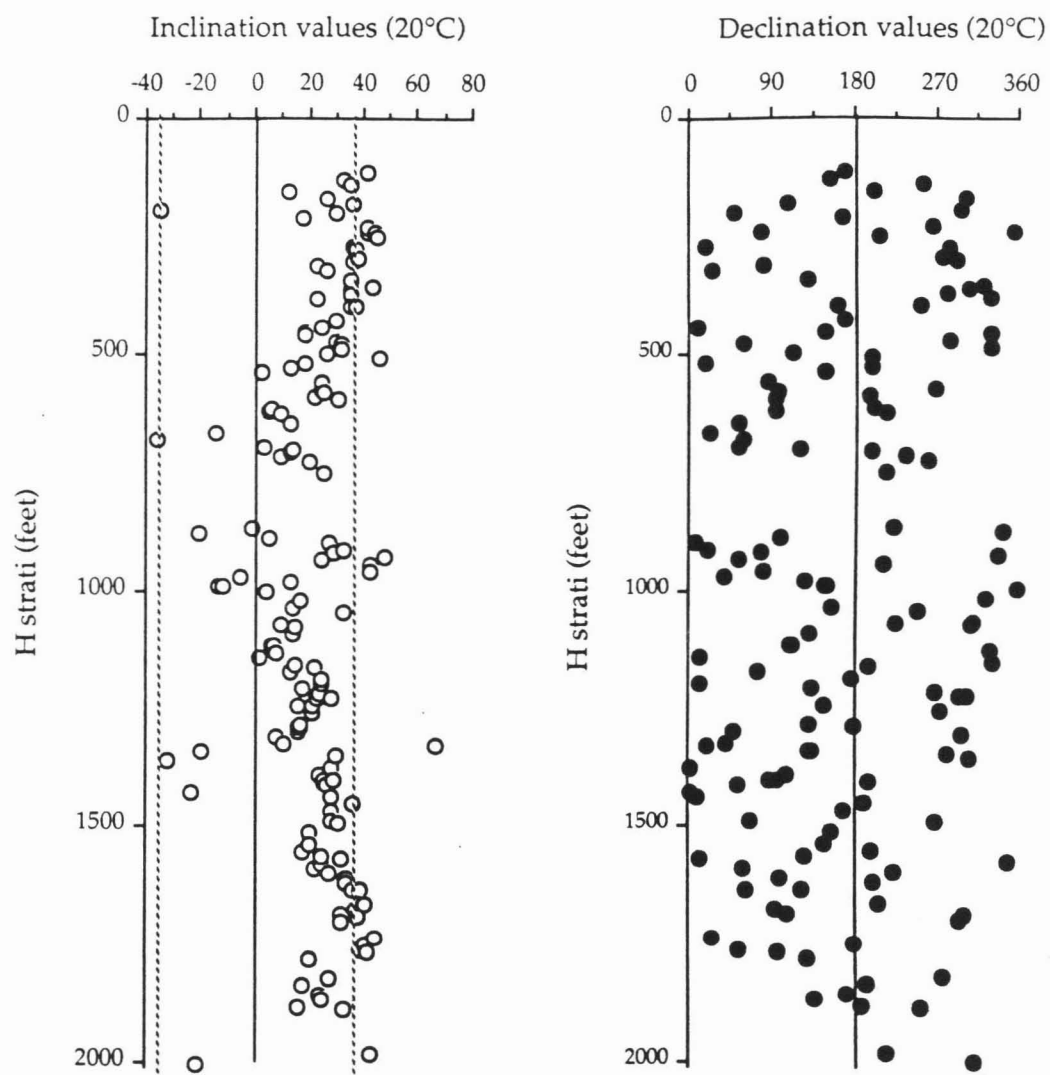


Figure 2

(ChRM) could be very accurately determined from these diagrams. It has been made calculating the Fisher mean direction over at least 10 steps of the demagnetization. The final results are illustrated in Figure 3 with the declination and inclination values obtained before the demagnetization for the same samples. The points are almost superimposed both in declination and inclination indicating that at least in the studied samples, there is no "thermally viscous" component. Only one sample (256 at 1071 feet) show a small viscous component: the declination of that sample does not change and the inclination varies about the horizontal plane. Even for that sample, a ChRM could be accurately defined.

II - 3. Alternating field demagnetization

Because the thermal demagnetization is sometimes unefficient to remove possible secondary component due, for example to lightning, we have checked on a few samples that the AF and the thermal demagnetization yield similar results.

Eight specimens on the same level of those studied by thermal demagnetization were analysed. We have chosen a zone (between 990 and 1400 feet) in which the direction of some of the Characteristic Remanent Magnetization (ChRM) determined by thermal demagnetization were characterized by negative inclination values (see dotted area in Figure 3). The AF demagnetization diagrams are reported in Appendix 3 in the same way as the ones obtained from thermal demagnetization. 14 steps have been measured (mT): 0 - 5 - 10 - 15 - 20 - 25 - 30 - 37.5 - 45 - 52.5 - 60 - 70 - 85 - 100.

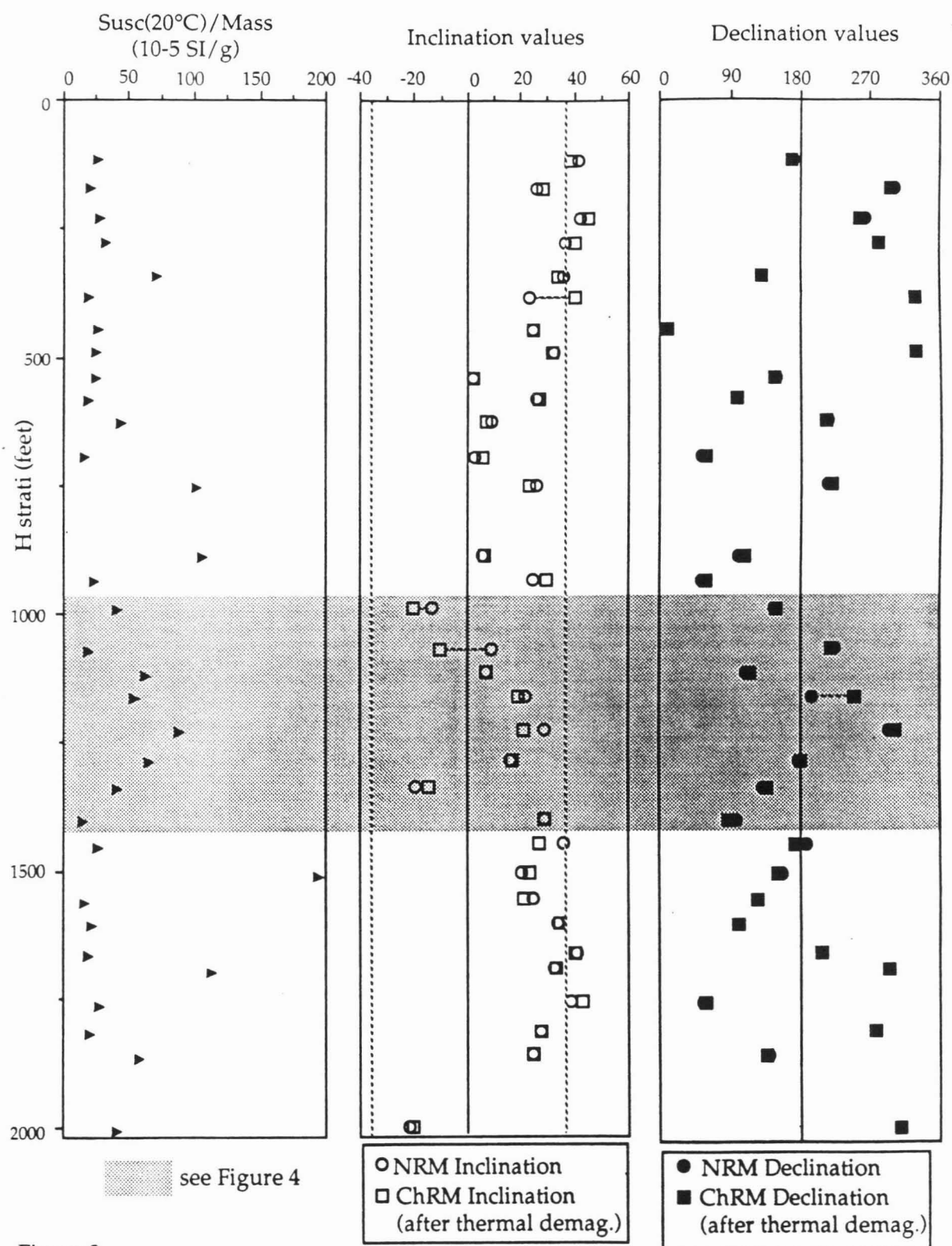
Sometimes, a small viscous component can be observed and it is removed after the first to the fourth steps. Then, the magnetization decreases regularly to the origin with a perfectly stable direction. The direction of this ChRM could thus be defined very accurately (numerical values in Appendix 5).

This direction is exactly the same as the one obtained by thermal demagnetization (Figure 4) indicating that no major overprint has affected the samples. In the same way, the low-field susceptibility values also reported in Figure 4 show that two samples from the same level have the same characteristics.

III - Magnetic mineralogy analysis

So far, thermomagnetic analyses have been performed on each specimen thermally demagnetized. The curves are given in Appendix 4. The analysis is made by heating a small amount of powder from room temperature up to 690°C

PRELIMINARY RESULTS FROM CORE SOH4
(about 1 sample every 6 flows)



**COMPARISON OF THE ChRM DIRECTIONS
OBTAINED USING THERMAL AND AF
DEMAGNETIZATIONS ON 8 SAMPLES FROM
CORE SOH4 (990 TO 1400 FEET)**

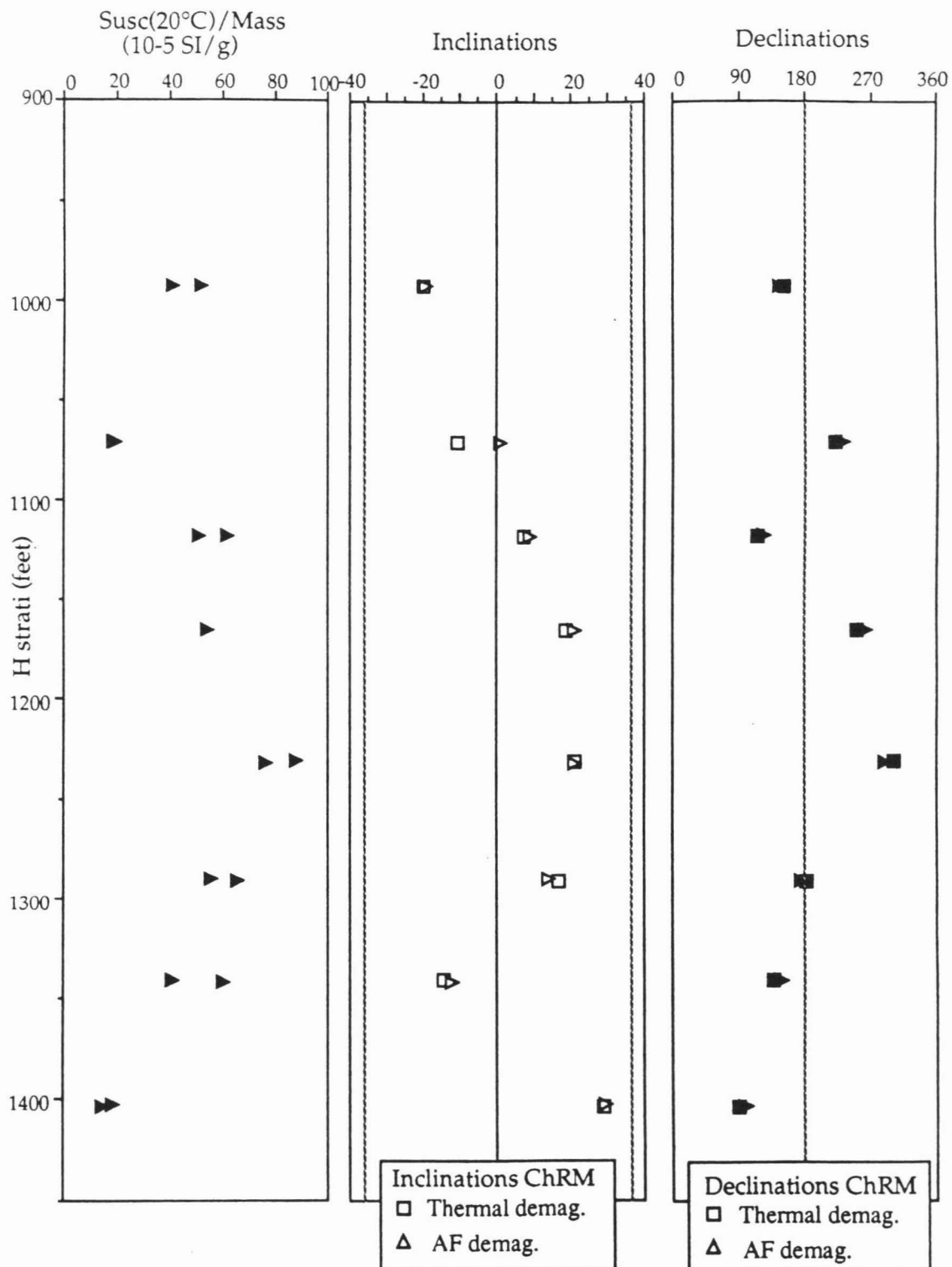


Figure 4

(black dots) and to cool it down (white dots) using an horizontal Curie balance. One measurement of the intensity is made every 5°C and the heating speed is 25°C per minute, in an Argon atmosphere to avoid possible oxydation of the samples.

Most of the studied samples show a perfectly reversible curve indicating that no new mineral has been formed during the heating process (Figure 5a). Moreover, the final temperature to which the magnetization is completely removed is about 580°C. This is typical for low-Ti content magnetite. Sometimes, the cooling curve does not reach the same poitn at room temperature indicating that even with Argon atmosphere, a small part of the magnetites has been oxydized into hematite at high temperature (Figure 5b)

Some curves are characterized by a change in the slope at about 300 - 450°C showing that a magnetic phase has been transformed (Figure 5c). The only remaining phase is magnetite as shown by the Curie temperature both at the end of the heating part and for the cooling part.

IV Paleointensity measurements

Because the determination of the geomagnetic paleointensities from lava samples is a very slow experiment, we have made this determination on 4 samples so far. They have been selected at different stratigraphic height. We have used the Thellier and Thellier method (1959). The samples have been heated at 100 - 150 - 200 - 250 - 300 - 330 - 370 - 420 - 460°C with controls at 100°C after 200°C, at 200°C after 330°C and at 330°C after 420°C.

For three samples, about 50 to 70% of the ARN has been removed at 420-460°C (Figure 6a). The fourth one (226 at 945 feet) show a much more rapid decrease of the intensity (Figure 6d). For all the samples, it has been possible to determine a paleointensity value with a great accuracy. They are (Appendix 5):

samples	strati. H (feet)	Paleointensity (μ T)
88	461	34.7 ± 1.47
226	945	42.5 ± 1.15
333	1352	31.3 ± 3.3
456	1838	27.2 ± 1.38

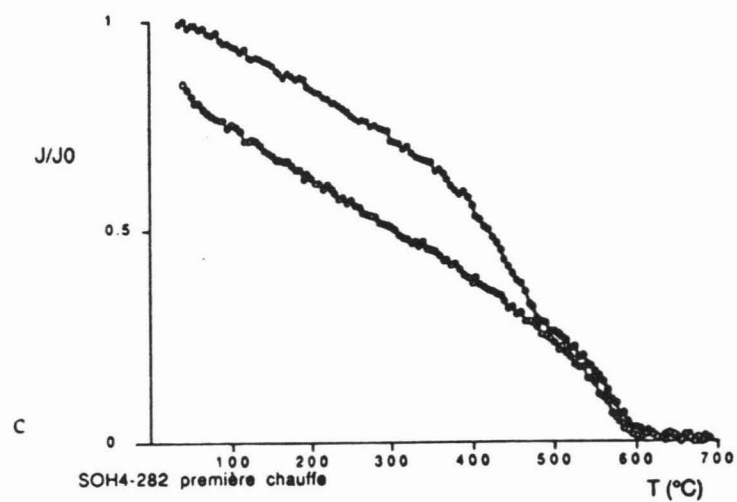
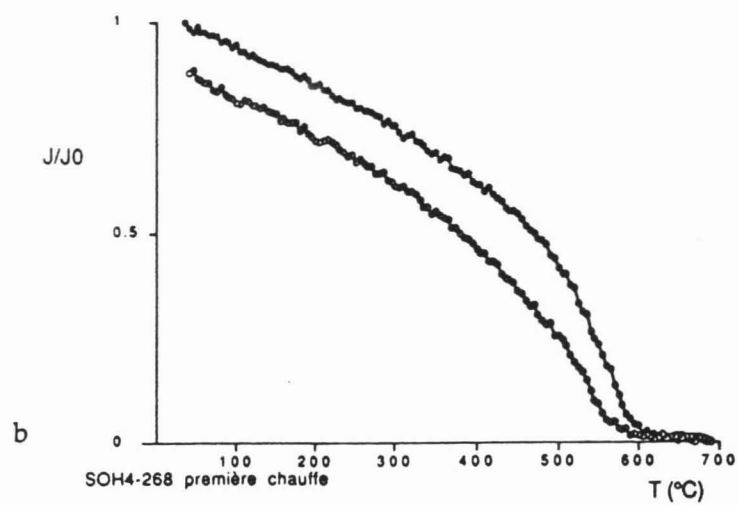
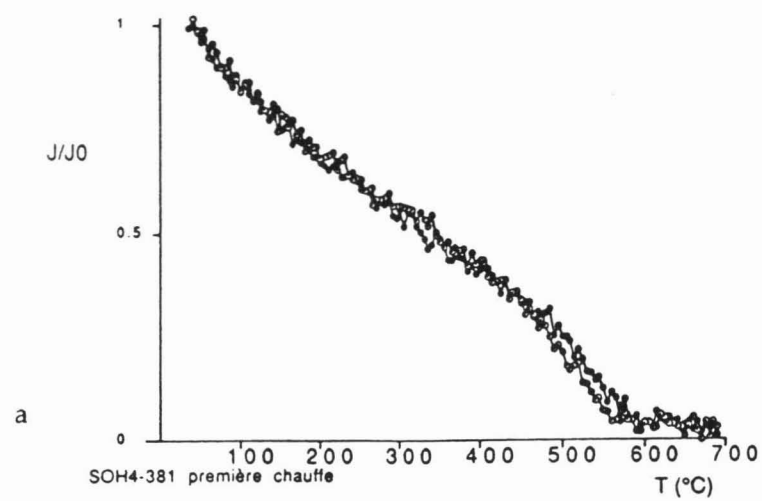


Figure 5

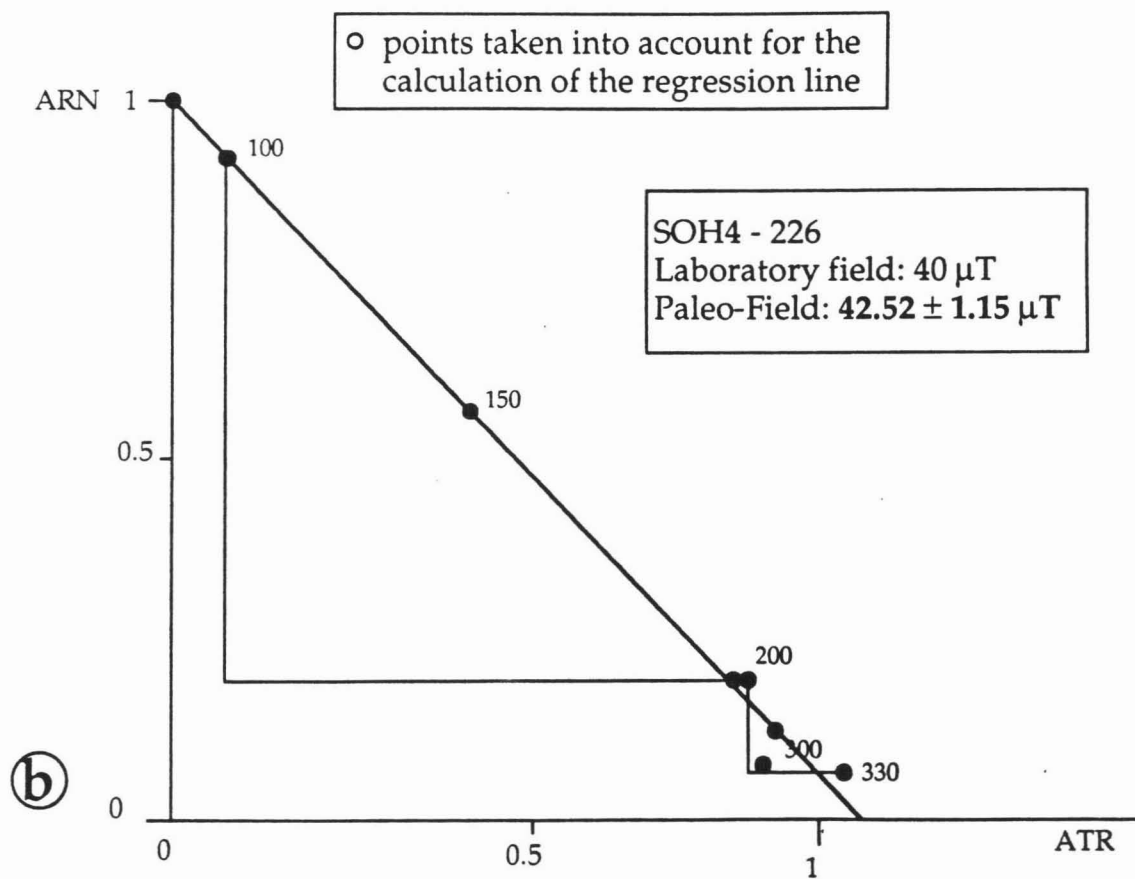
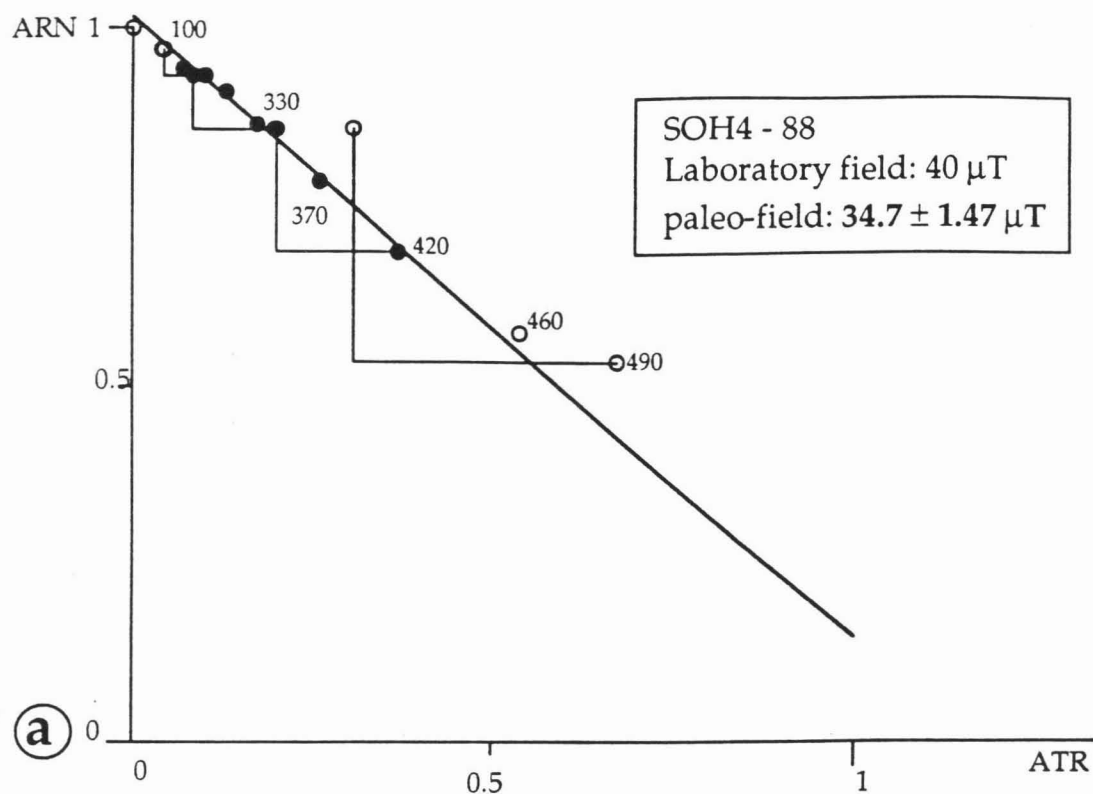


Figure 6

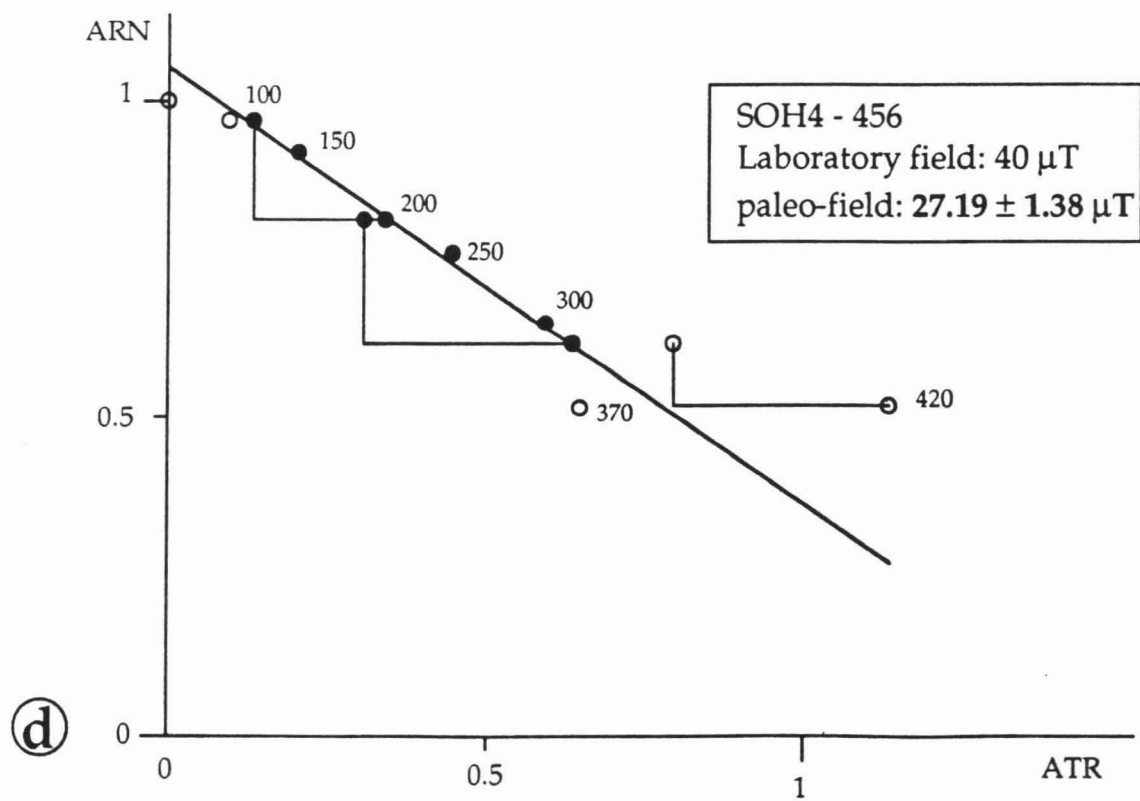
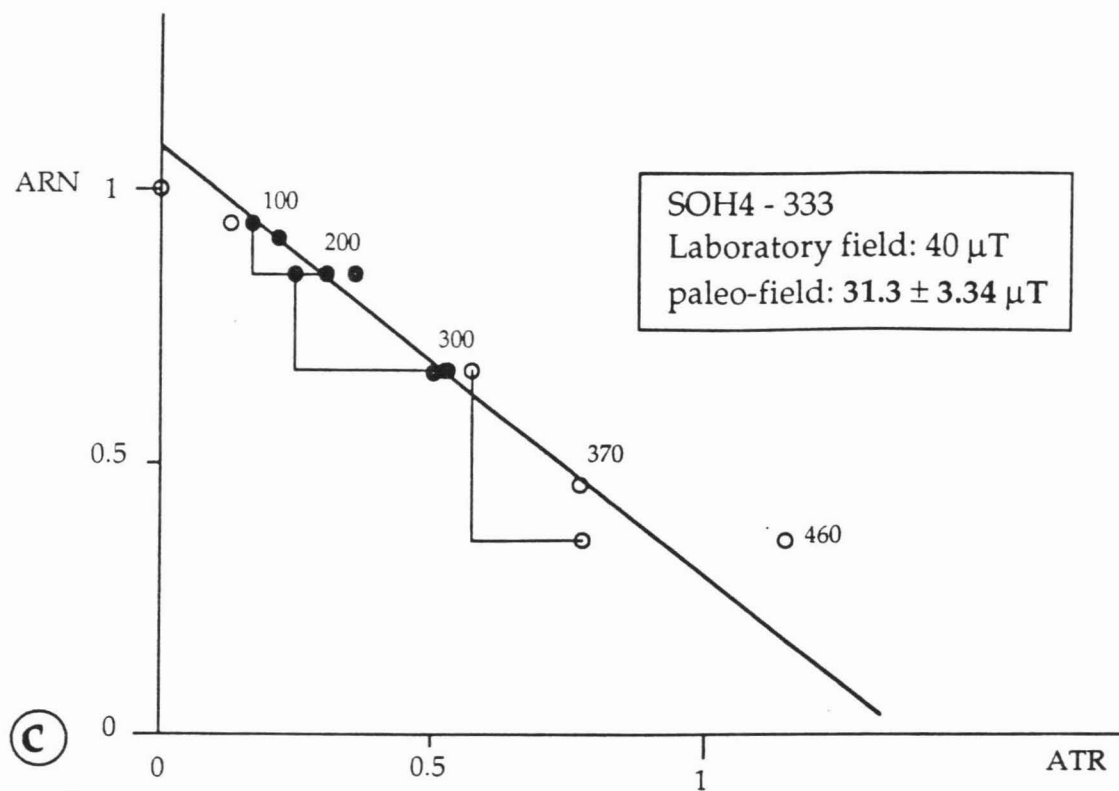


Figure 6

FIRST RESULTS ON K/Ar DATING OF SOH4 1550'7".

The sample of lava from SOH4 drill hole (1550'7" deep) have been dated according to the technique developed at the CFR (CNRS-CEA) especially devoted to the detection of very low radiogenic argon levels, generally applied to the dating of very young rocks. A reprint, presenting the technique is joined to the present report.

1 - Analytical technique.

The main problems limiting the accurate dating of young volcanics is linked to:

- 1) the increasing dilution of radiogenic argon in contaminating atmospheric argon which needs the most accurate determination of a low radiogenic argon percentage in the total argon with increasing dilution rate within that contaminant argon component.
- 2) the systematic error due to enclaves and possible inheritance from early cristallisations and xenolits.

1.1) Error magnification with increasing contamination level.

In order to date accurately rocks of the recent period (0-200 Ka), we have developed a particular technique for potassium-argon dating based on a double comparison between argon extracted from the sample and atmospheric argon. This makes it possible to detect radiogenic argon percentages down to 0.1 %. It corresponds typically to some thousand of years in a 1% potassic lava and less than one thousand years in potassium rich minerals.

That accuracy has been cross-checked with other dating techniques (e.g. thermoluminescence and radiocarbone) and tested on zero age reference lavas. The above mentioned precision depends on the total amount of argon present in the mineral essentially contaminant atmospheric argon when processing very young rocks. That contamination depends on the rock type. It increases drastically with the vesicular and glassy facies and rock types resulting from intrusive and explosive activities. It depends also on the freshness of the material and increases with alteration and deuteric evolution of the material.

The potassium is measured independently by flame photometry and/or atomic absorption spectrophotometry. The latter analytical technique makes it possible to determine the K content with a relative accuracy of 1%, within a range of K content of between 0.1 and 10%. The cross-checking of the two techniques - atomic absorption and flame photometry - permits to determine precisely the K content and to identify possible matrix effect (flame photometry) and/or interference effect linked to alkaline content (atomic absorption).

The whole technique is based on the selection of homogeneous mineral phases - allowing the separate measurement of potassium and argon - significant of the event to be dated.

1.2) selection of the mineral phases.

In order to date accurately the flowing or the deposits of a volcanic unit, the mineral phase cooled and solidified at the surface, at atmosphere during the volcanic event must be selected.

The groundmass, made of microlites or glass, generally corresponds to the phase solidified during the emplacement. Moreover, it concentrates the potassium, which is an hygromagmaphile element ; in the microlitic groundmass it is distributed at the limit between the grains ; the selection of polycrystalline microlitic groundmass grains offer the most homogeneous, potassium rich phase for dating. In that purpose, the pheno- and xeno-crysts are eliminated which permits to get rid of the possible inheritance of extraneous argon from early cristallizations or from the surroundings. This is obtained by means of combined gravimetric (heavy liquids, essentially bromoform diluted in ethanol or diodométhane diluted in acetone) and magnetic separations.

When possible, a pure mineral phase (e.g. feldspars phenocrysts) is analyzed separately in order to check the consistence between the potassium-argon ratios in two different mineral phases with various K content, argon contamination level and cristallisation conditions.

1.3) Error estimate.

The age is calculated according to the formula :

$$t = 4154 \log (1 + 142.7 \text{ } ^{40}\text{Ar}^*/\text{K}),$$

using the International Conventional Constants proposed by Steiger and Jäger (1977).

It can be simplified for very young rocks (< 1 Ma) :

$$t = \text{ } ^{40}\text{Ar}^* / 1.045 \cdot 10^8 \times \text{K}$$

Where $\text{ } ^{40}\text{Ar}^*$ is the amount of cc of radiogenic $\text{ } ^{40}\text{Ar}$,
and K the weight (g) of natural potassium

the radiogenic ^{40}Ar is obtained by multiplying the total ^{40}Ar by the radiogenic percentage ; the later is deduced from the comparison between atmospheric $^{40}/^{36}$ isotopic ratio (R_a) and sample argon $^{40}/^{36}$ isotopic ratio (R_e), according to the relation : $T\% = 100 \times (R_e - R_a)/R_e$.

Our technique of measurement limits the errors to three terms :

- the error on K content estimated from standard replicate measurements to 1% in relative (2σ) ;
- the error on the calibration of the total argon amount which corresponds to $\pm 0.5\%$ in relative (2σ) deduced from replicate measurements of international reference material and volumetrical calibration from a known amount of atmospheric argon ;
- the relative error on the radiogenic ^{40}Ar percentage deduced from the limit of detectability when correcting for the atmospheric contamination ; the limit of accuracy on ^{36}Ar measurement determines that absolute limit to $\pm 0.1\%$, that is in relative $e\% = 100 (0.1\%/T\%)$.

The error is calculating by making the quadratic sum of these three relative errors. When dealing with very young rocks, the later error on radiogenic ^{40}Ar level is predominant and tends to infinite close to zero. For increasing ages, its relative value decreases progressively and tends to $\pm 1.12\%$ relative error on the age (2σ) for ages larger than some million years. All the errors are quoted at 2σ (95 % confidence level).

2 - Analytical results.

The results are reported in the following tables. They correspond to the mean value of at least two replicate measurements independent for Potassium (0,1 to 0,3 g aliquotes) and the first result for Argon (1 to 3 g aliquotes) analysis.

Name	Phase	%K	% $^{40}\text{Ar}^*$	$^{40}\text{Ar}^*10^{10}\text{at.g}^{-1}$	Age (Ka) $\pm 2\sigma$
SOH4 1550'7"	Past	0,500 \pm 0,005	0,273	2,1909 \pm 0,802	42 \pm 15

The following table gives the conditions of separation of the measured phase.

Name	Phase	Density
SOH4 1550'7"	past	3,05-3,02

2)Conclusions

The measured age is about 42 Ka with an estimate error of 15 Ka, which is quite important. The facies of the dated sample was very vesicular and did include cumulative enclaves inherited from early cristallisations. So i don't think that this age alone is significant and it has to be cross-checked with other samples from the same and other drill-holes at close stratigraphical positions. There is also an other problem with that sample. We have done a second measurement which gave a negative age. That result is explain by the presence inside the gaz extracted from the rock of an isotopic mass close to 36 which has not been eliminated during the purification of the gaz. So the isotopic ratio $^{40}\text{Ar}/^{36}\text{Ar}$ of the sample has been under-estimated and did appear to be lower than the isotopic ratio $^{40}\text{Ar}/^{36}\text{Ar}$ of the atmosphere.

So, as a first conclusion we can say that the most significative result of the measurement is not the obtained age but the possibility to detect radiogenic argon in young tholeiitic basalts.

For the next samples, i propose to choose more massive samples and as unaltered as possible.